Identification of Traumatic Subarachnoid Hemorrhage Using Susceptibility Weighted Imaging

J. Lei[1], Z. Wu[2], M. Liu[1], T. Han[1], and E. M. Haacke[2,3]

[1]Radiology, Tianjin Huanhu Hospital, Tianjin, China, People's Republic of, [2]Biomedical Engineering, McMaster University, Hamilton, On, Canada, [3]Radiology, Wayne State University, Detroit, MI, United States

Introduction: The occurrence of subarachnoid hemorrhage (SAH) in traumatic brain injury (TBI) is 12% ~ 53% and related to poor outcome (1, 2). Early diagnosis of SAH and active intervention in removing hemorrhage from subarachnoid space is of great significance in the management of acuteTBI. Susceptibility weighted imaging (SWI) has been successfully applied in TBI and proved to be 6 times more sensitive than conventional gradient echo imaging in detecting intra-cerebral hemorrhage (3). To date, no study has been done using SWI to detect SAH. In this study, we explore the sensitivity of SWI in detecting SAH, compare it with CT and FLAIR, and summarize the characteristics of SAH on SWI.

Materials and Methods: Both MRI and CT data from 20 acute TBI patients (16 males and 4 females, 39.1±19.6 yrs) with SAH were retrospectively reviewed by two neuroradiologists. The CT (Siemens, SOMATON) acquisition parameters were as follows: x-ray tube current = 360 mA, kvp = 120 kV, resolution = 0.5 x 0.5 x 6 mm^3. Four MRI sequences were collected at 3T (Siemens TRIO), including: T1W, T2W, FLAIR and SWI. According to the location, five regions of SAH were defined: interhemispheric fissure (IF), sylvian cistern (SC), sulci of cerebral convex (SCC), basilar cistern (BS) and intra-ventricle (IV). Basilar cistern includes pontine, interpeduncular, ambient, and quadrigeminal cisterns. SAH is defined as high density on CT in the subarachnoid space, hyper-intense signal on FLAIR, and hypo-intense signal on SWI with the normal veins excluded. The two neuroradiologists first independently reviewed CT, FLAIR and SWI separately and then discussed their results and came to agreement.

Results: A total of 63 SAH regions were identified from CT, FLAIR and SWI. Sensitivity of detecting SAH regions for CT, FLAIR and SWI were 84%, 33% and 68%, respectively. Table1 shows the number of cases identified by each method in each region and how FLAIR and SWI agreed with CT results (the numbers in the brackets are cases identified both by FLAIR and CT or SWI and CT). SWI identified all five cases of intra-ventricular hemorrhage found on CT and three more cases which CT failed to show (Fig 1). FLAIR showed low sensitivity in all the regions. SAH on SWI showed as very low signal in the subarachnoid space with thicker diameters and rougher boundaries (short arrows in Fig 2C) than vein (long arrow in Fig 2C). SAH showed aliasing in most cases on phase images (Fig 1 and 2). SWI found two cases in which SAH was confined to one sulcus with a very small amount of hemorrhage but it was confirmed by its shape and obvious aliasing in the phase images. However 6 cases of sylvian cistern and 3 cases of basilar cistern SAH were missed by SWI.

Table 1	IF	SC	SCC	BS	IV	*Total*
CT	10	12	21	5	5	53
FLAIR	5(5)	4(4)	9(6)	2(1)	1(1)	21
SWI	9(7)	7(6)	15(13)	4(2)	8(5)	43
Total	12	13	23	7	8	63

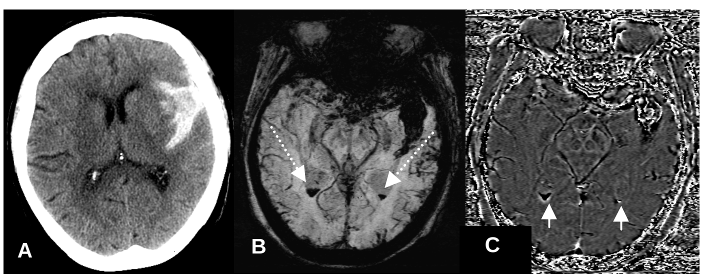

Fig 1: CT (A) showed high density in the sylvian cistern. SWI (B) not only showed hemorrhage in the same region, but also showed the blood level inside the ventricles (long arrows) which CT failed to show. SWI phase (C) showed blood products with aliasing effect (short arrows).

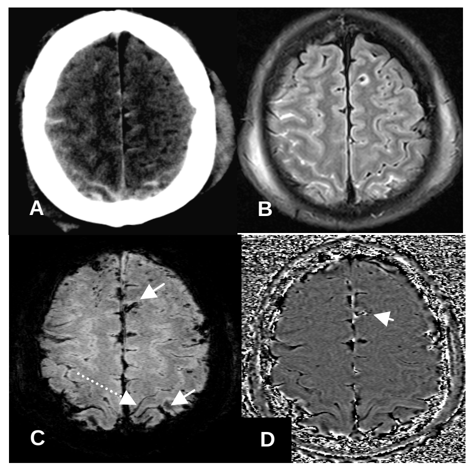

Fig 2: CT showed high density in the interhemispheric fissure and the convex sulci. FLAIR (B) showed high signal inside the sulci. SWI (C) showed SAH (short arrows) while the vein (long arrow) is smooth and thin. The SWI phase image (D) showed aliasing (arrow head).

Discussion: CT has long been considered the first choice in the detection of acute SAH. However the ability to detect SAH is dependant on the interval after onset, the amount of hemorrhage, the resolution of the scanner and the skills of the radiologist. The positive rate of SAH detected by CT is 95% in 24 hours, 80% 5 days later and 50% 7 days later (4). One case found in our work showed basilar effacement on SWI but was missed by CT. CT was done 4 days after trauma and MRI 7 days after. When hemoglobin is gradually degraded, the attenuation of the blood may not be shown as high density in the CT scans. SWI is sensitive to all the products of hemorrhage in different stages including deoxyhemoglobin, methemoglobin and hemosiderin. SWI has the potential to detect SAH in the acute and subacute/chronic stage. There are two cases with a small amount of SAH missed by CT. The slice thickness of CT in this study was 6 mm. Partial volume effects and a small amount of hemorrhage may account for the false negative in this case. SWI has been proved very sensitive to very small amount of hemorrhage. SWI showed intra-ventricle hemorrhage clearly with great contrast between blood in CSF and surrounding parenchyma (Fig 1). FLAIR has been proved to be very sensitive in detecting acute SAH, but its sensitivity has been shown to decrease from 100% to 33% from acute to subacute/chronic stage (5). In this study, most patients received the MRI scan 5 days after TBI. This might be the reason that FLAIR has a very low sensitivity (33%). In the regions close to the air/tissue interface, the radiologists were very conservative with the dark signals shown in these areas because a lot of susceptibility artifacts took place there. This could explain why SWI missed a few cases. We have observed that in most cases SAH tends to show aliasing on phase images while veins rarely do for an echo time of 20ms at 3T. Although high pass filtering removes aliasing from the background such as air/tissue interface, it does not remove high spatial frequency aliasing (6). In this case, the aliasing became very useful in differentiating veins from SAH because veins don't alias, making it easier to identify SAH. However not all the SAH has aliasing on phase images. Some practice in reading SWI data and familiarity with normal venous structures are needed in order to recognize SAH.

Conclusion: SWI is better than CT in detecting small amounts of SAH and intra-ventricle hemorrhage and subacute/chronic SAH. SWI is not as good as CT in detecting basilar cistern SAH. Both taken together do a better job than either one separately.

Reference: 1)Taneda M et al, Neurosurg, 84:762, 1996; 2)Servadei F et al, Neurosurgery, 50:26, 2002; 3)Tong KA et al, Radiology, 227:332, 2003; 4)Broderick JP,et al, Stroke, 25:1342, 1994; 5)Yuan MK, et al, J Chin Med Assoc, 68:131, 2005; 6)Haacke EM, et al, MRM, 52:612, 2004.